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EXPERIMENT

TIME SYNCHRONIZATION OF REMOTE STATIONS USING SYNCOM SATELLITE

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OBJECTIVE

The primary objective of this experiment will be the accurate transfer of "Time" between two remote stations. As our goal, we intend to transfer UT-2 time, corrected Universal Time, from one Syncom station to another remote Syncom station using the Goddard Range and Range Rate equipment. One station will be designated the master and the other the slave. The proposed system will be capable of achieving time synchronization to an accuracy of .5 microsecond or less. Present time synchronization systems, (WWV or VLF), will only allow an accuracy of approximately 1000 microseconds. Included in our experiment is a method of verifying the time synchronization, measuring the system uncertainty, and maintaining accurate synchronization.

TECHNIQUE

In order to achieve this accurate synchronization of time, we have two major areas to cover, (1) the transfer and maintenance of time from the U.S. Naval Observatory to the master, (2) the transfer and maintenance of time between the two Syncom Ground Stations, via the Syncom Satellite.

Time Synchronization for the first area will be accomplished by the use of a portable clock which can easily be carried from point to point. This portable clock will first be calibrated for its drift characteristics and then carried to the U.S. Naval Observatory for the initial time synchronization to UT-2 time; it will then be carried by air to the master station and used to set the station clocks.

The second transfer of time between the two Syncom ground stations, will be the primary purpose of the experiment. This transfer will be accomplished using the Goddard Range and Range Rate System; this system determines distance by means of measuring and recording delay time so that this system can easily be utilized for transferring time between the two ground stations. The Goddard Range and Range Rate System has been capable of measuring the round trip time delay to the satellite to an accuracy of 0.1 microsecond.

After synchronization of the master station's time standard to NBS the master will at a prearranged time broadcast a pulse to the slave. The slave will then measure the delay, T_D, from the prearranged time at its station until it receives the pulse from the master. Immediately after receiving this pulse the slave will range to the satellite and measure the delay, T_2. The master will have measured the delay, T_1, from its own pulse sent at the prearranged time. The value of T_1 will be communicated to the slave by means of a teletype link.

With the delay information the slave can compute (see diagram) the amount by which it is out of time synchronization with the master and correct its time standard. After the correction is made the synchronization will be verified by reversing the procedure.

It is extremely important that the experiment be performed at periods of minimum satellite radial velocity, and that accurate predictions of range and velocity be provided. A radial velocity component of 50 feet per second will cause an error of 0.1 microsecond per second; so that in order to materially erase the problem of velocity correction, the experiment will be performed when the radial velocity is at a minimum for the slave station.

Once time has been transferred to the station, it is necessary to maintain accurate synchronization in order to accomplish the experimental objective. The problem involved is due to the drift of the oscillators. A drift of one microsecond per hour is equal to an oscillator stability of approximately 3×10^{-10}/hour. Oscillator stabilities of this order of magnitude can be achieved; we have lab units which have shown a stability of approximately 1×10^{-11}/day (1 microsecond per day).

Even with this stability oscillators have a drift characteristic which must be measured and corrected for in order to adequately maintain synchronization. In order to make these corrections VLF (Very Low Frequency) techniques have been developed which enable the station to continuously monitor their frequency and maintain a daily error of less than 5×10^{-11}; if the monitoring is performed for one to two weeks the daily error can be reduced to 1 to 2 parts in 10^{11}. We propose to use this VLF technique at both the Syncom ground stations for maintaining an accurate frequency and time synchronization.

Another important factor is the ability to reset the time of the station clocks accurately. The present Syncom station clocks do not allow the operator to make fine adjustments of the time in order to synchronize their station with another time reference. We propose to furnish, along with other equipment, clocks with the ability to set time to 0.1 microsecond.

OBTAINABLE PRECISION

The measurable time difference using Range and Range Rate is ±0.1 microsecond, and the measurable time delay due to satellite velocity using Range and Range Rate is ±1 nanosecond.

The differential phase shift in receivers and transponders due to Doppler and signal level change is expected to be less than 0.1 microsecond.

Using VLF, and the portable time standard the measurable frequency change of the oscillators will be about 1 to 2 parts in 10^{11} per day.

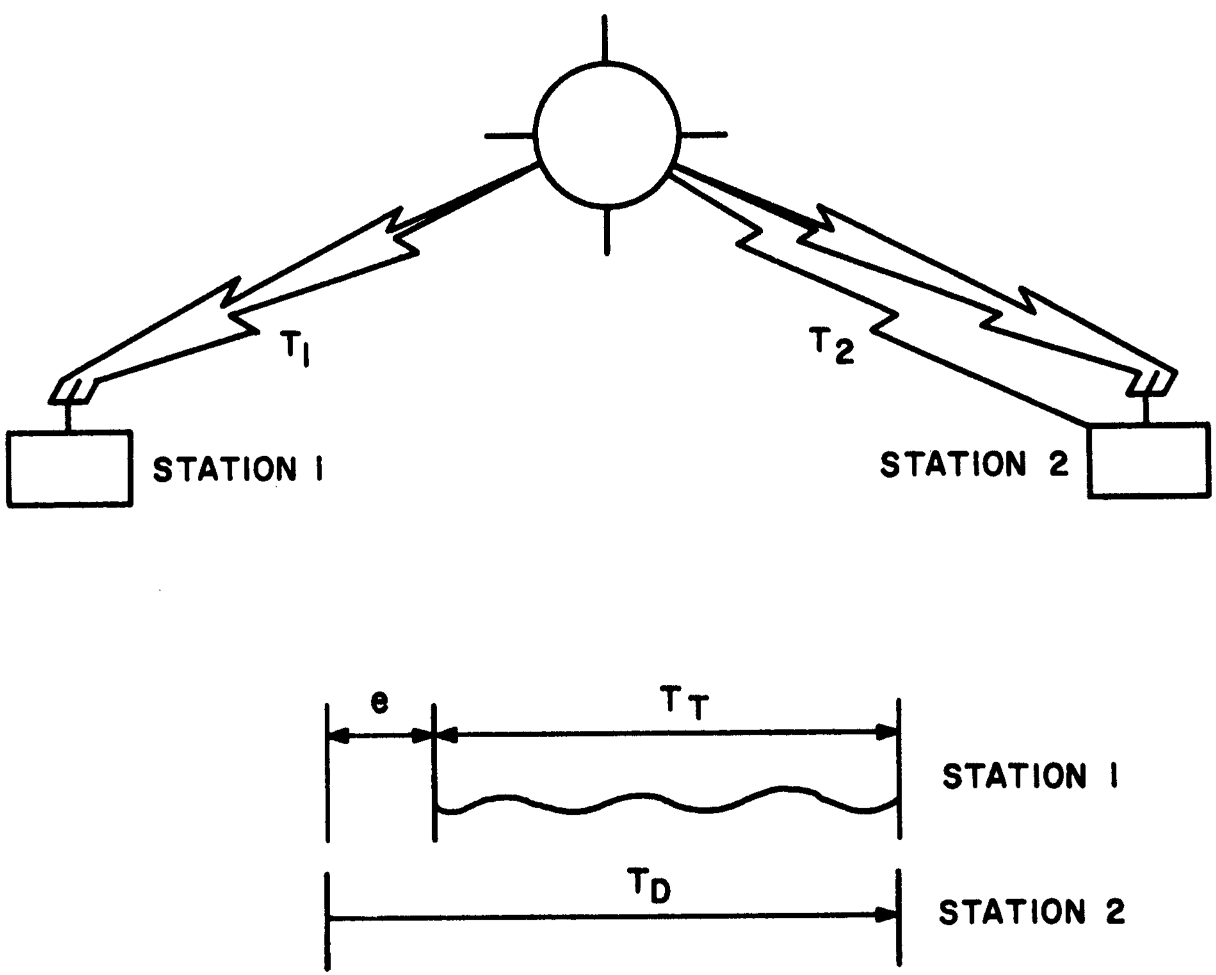
Thus, with provision for the proper peripheral equipment, there is a high probability that two-way time synchronization accuracies of less than .5 microsecond can be achieved, and actual proof of the accuracy obtained can be demonstrated.

EQUIPMENT REQUIRED

The Range and Range Rate System equipment is in operation, at both the stations, as is the Syncom satellite. Also at each station there is an HP-104 A oscillator.

The new equipment consists of 2 auxiliary digital clocks that can be set to 0.1 microsecond, a portable clock, 2 VLF receivers, and two standard oscillators more stable than the HP-104 AR for use with the auxiliary digital clocks.

The auxiliary clocks, portable clock, VLF receivers, and the standard oscillators are already in-house or on purchase order.



T_D = DELAY TIME
T_T = TRANSMISSION TIME
$T_T = T_2 + T_1$

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SYNCOM EXPERIMENT